Sudakov Resummation and Finite Order Expansions of Heavy Quark Hadroproduction Cross Sections*

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Long- and short-distance dynamics in inclusive hadronic hard-scattering cross sections are factorized in Quantum Chromodynamics (QCD) into universal, non-perturbative parton distribution functions and fragmentation functions, and perturbatively calculable hard scattering functions. Remnants of long-distance dynamics in a hard scattering function can, however, become large in regions of phase space near partonic threshold and dominate higher order corrections. Such Sudakov corrections assume the form of distributions that are singular at partonic threshold. Threshold resummation organizes these double-logarithmic corrections to all orders, thereby extending the predictive power of QCD to these phase space regions.

The organization of such corrections to arbitrary logarithmic accuracy was first achieved for the Drell-Yan cross section. An equivalent level of understanding for general QCD processes with more complex color structures at the Born level has been achieved more recently. The resummation of Sudakov corrections in such processes to next-to-leading logarithmic (NLL) accuracy requires understanding how these structures mix under soft gluon radiation. Processes involving Born-level two-particle scattering may be described in either single-particle inclusive (1PI) or pair-inclusive (PIM) kinematics.

Resummed cross sections constitute an approximate sum of the complete perturbative expansion if, at each order, the Sudakov corrections dominate. Resummed results for heavy quark production at leading logarithmic accuracy have been presented some time ago [1]. We employ the resummed cross sections as generating functionals of approximate perturbation theory. We expand the NLL resummed cross sections and derive complete analytic expressions through next-to-next-to-leading order (NNLO) for double-differential heavy quark cross sections in two different kinematics: heavy quark pair-inclusive and single-heavy quark inclusive. To achieve next-to-next-to-leading logarithmic (NNLL) accuracy we include color-coherence effects and contributions due to soft radiation from one-loop virtual graphs via matching conditions.

We provide values of the approximate NNLO top cross section at 1.8 and 2.0 TeV and the approximate NNLO bottom cross section at 41.6 GeV based on a combination of the results and their uncertainties. Two errors are assigned to the resulting cross section. The first is due to the kinematics-induced ambiguity and is the difference between the central value and the $\mu = m$ values obtained in 1PI and PIM kinematics alone. The second is the weighted average of the scale uncertainties in the two kinematics, giving more weight to smaller scale uncertainties. Thus we obtain the following NNLO top production cross sections at the Tevatron,

$$\sigma_{t\bar{t}}(1.8\,\mathrm{TeV}) = 5.8 \pm 0.4 \pm 0.1 \ \mathrm{pb}, \quad (1)$$

$$\sigma_{t\bar{t}}(2.0\,\mathrm{TeV}) = 8.0 \pm 0.6 \pm 0.1 \ \mathrm{pb}. \quad (2)$$

The HERA-B cross section to NNLO is

$$\sigma_{b\bar{b}}(41.6\,\mathrm{GeV}) = 30 \pm 8 \pm 10 \ \mathrm{nb}. \quad (3)$$

Note that the scale uncertainty is considerably smaller than the kinematics uncertainty for top production.

[1] E. Laenen, J. Smith, and W. L. van Neerven, Nucl. Phys. **B369** (1992) 543.

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